The Estimation of Pollution Loading of Non-Point Source in Expressway

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ABSTRACT

The objective of the research was to determine the pollutant unit load from expressway landuses. It was determined by performing monitoring during a storm at various expressway landuses. During recent 2 years research periods the monitoring were performed on 8sites.4. From this research, the following results were determined. The pollutant unit loads were determined to 43.6kg/㎢·yr for BOD, 8.81kg/㎢·yr for TN, 1.40kg/㎢·yr for TP. Long-term monitoring is really needed to determine the appropriate pollutant unit load. Therefore, in order to have useful unit load, more monitoring will be needed. BMPs having the mechanism of sedimentation, infiltration and filter show the high removal efficiency, higher than 70% for particulate materials and more than 50% for metals, respectively.

1. INTRODUCTION

Non-Point Source (NPS) pollutants are originating from various landuses such as commercial, residential, industrial, expressways, streets etc. The main factor changing the landuse is construction projects. Especially the expressway construction projects are an important NPS because of its high imperviousness rate and high vehicle activities after constructing. Most of developed countries are classifying the expressway construction projects as highly impaired NPS. Therefore, Korea MOE (Ministry of Environment) have made the new water quality program, which are Total Daily Maximum Load (TMDL) and NPS control program. In these programs, the expressway construction projects are classified as the landuse requiring best management practices (BMPs) for NPS pollutant control.

However, current TMDL program in Korea is using only one pollutant unit load for urban landuses to determine the possible pollutant loadings after construction. Actually the urban areas are including various landuses, which are residential, commercial, industrial, transportation such as expressway, parking lot, road, etc. Of the various landuses in urban areas, the transportation landuse is the area accumulating lots of NPS pollutant during dry seasons because of vehicle and human activities.

Therefore, the objectives of the research are to determine the pollutant unit load from expressway landuses. It will be determined by performing monitoring during a storm at various expressway landuses. The result will be used to change and separate the pollutant unit load of expressway from urban areas in TMDL.

2. EXPERIMENTAL METHOD

Monitoring of NPS Pollutants in Expressway

During recent 2 years research periods the monitoring were performed on 8 sites. However, we added 6 more sites to get enough data for determining the EMCs and unit loads. Total monitoring sites are classified to 4 different landuses, which are expressways, service areas, tollgates and slopes. The reason of this kinds of landuse classification is to effectively determined the representative EMCs and unit loads from various expressway landuses. The number of monitoring site can be classified to 6 sites for expressways, 3 sites for tollgates, 1 site for service areas and 1 site for slope.

Table 1. Catch basin Area and Imperviousness Rat e

Site	Locations	Catch basin Area(m^2)	Imperviousness Rate(%)
H1	expressway No. 1 (Cheonan tollgate)	2,760.2	100
H2	expressway No. 1 (Giheong service area)	9,522	-
H3	expressway No. 15 (Bridge at Maesong IC)	282.7	100
H4	expressway No. 15 (Tollgate at Maesong IC)	1,176.1	100
H5	expressway No. 251 (Yousung 1)	1,170	100
H6	expressway No. 251 (Yousung 2)	936	-
T1	expressway No. 251 (Gaeryoung tollgate 1)	661.5	100
T2	expressway No. 251 (Gaeryoung tollgate 2)	311.2	100
T3	expressway No. 1 (Suwon tollgate 1)	854.7	-
S1	expressway No. 1 (Giheong service area)	1,000	-
SL	expressway No. 1 (Slope near Cheonan tollgate)	854.7	4.68

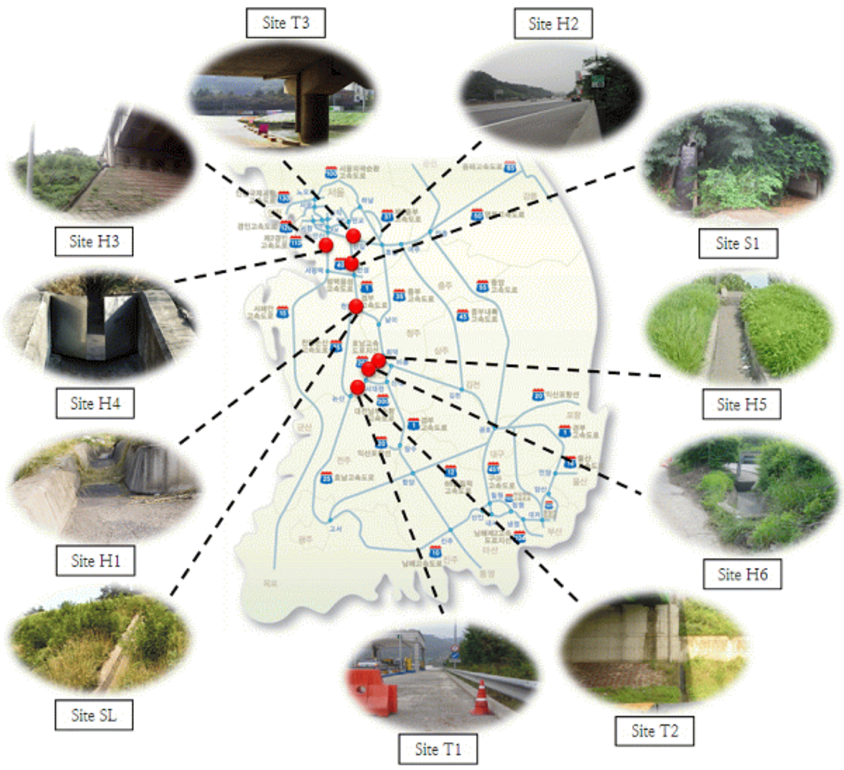


Figure 1. Monitoring Locations

The important factors for unit loads can be the number of rainfall events, occurrence frequency of rainfall, rainfall ranges and EMCs of runoff. In order to determine the unit load, the 30 years rainfall data from KMA (Korea Meterological Administrations) were used. The Buyeo rainfall station are used for determining the unit load from tollgates such as T1 and T2 sites because there are no rainfall stations in Gaeryong city. The Buyeo is the nearest rainfall station from the sites. Total four rainfall stations were selected for this research, which are Suwon, Cheonan, Daejeon and Buyeo. The Cheonan station was used for analyzing the monitoring sites of H1, H2, S1 and SL. The Suwon station was used for analyzing the monitoring sites of H3, H4 and T3. The Daejeon station was used for analyzing the monitoring sites of H5 and H5. The Buyeo station was used for analyzing the monitoring sites of T1 and T2. For determining the pollutant unit loads, the 30 years rainfall data for each site was used.

Monitoring of BMP Facilities

Monitoring locations for evaluation the NPS BMP facilities were selected on Giheung tollage and Gaeryoug tollgate. The locations were named on SWT1 and SWT2. Filter type's BMPs were established on the sites. The settling tank was placed before filter layer for pre-treatment of the runoff and the used media was zeolite and so on.

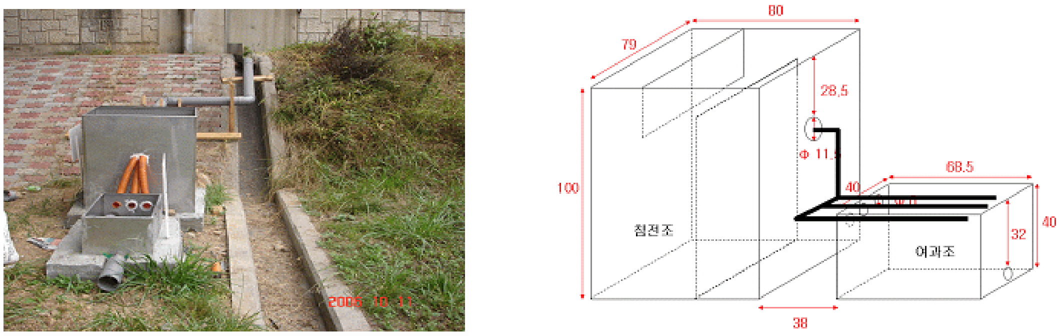


Figure 2. Schematics of BMP facility

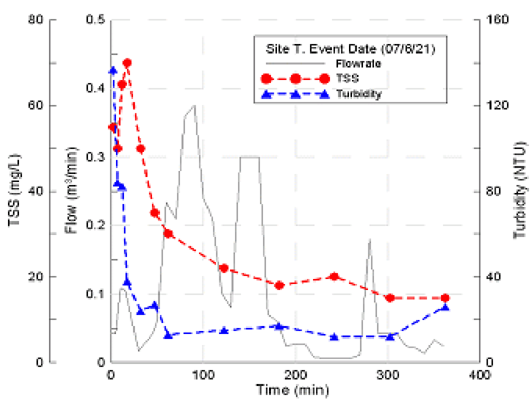
3. RESULTS AND DISCUSSION

Determination of EMCs

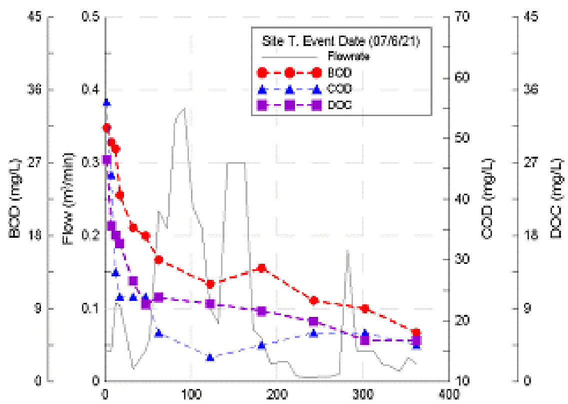
The washoff characteristics of pollutants were visibly analyzed using hydro- and polluto-graphs and visual concentrations. Most of events show the first flush phenomena because of high imperviousness rate and high mass accumulation.

The monitoring for many rainfall events was performed on each site. The monitoring performed on each site was 59 events for expressways, 33 events for tollgates, 10 events for each service areas and slopes.

Figure 3. visual concentration



(a) TSS, Turbidity



(b) BOD, COD

Figure 3. The hydro and polluto graphs

The statistical summaries of monitoring events at expressways shows 2～18 days for ADD (Antecedent Dry Days), 1.5～89 mm for total rainfall, 1～23 hrs for runoff duration and 0.3～24 mm/hr for average rainfall intensity. The statistical summaries of monitoring events at tollgates shows 2 ~ 15 days for ADD (Antecedent Dry Days), 3～77.5 mm for total rainfall, 0.5～20 hrs for runoff duration and 0.8～9.0 mm/hr for average rainfall intensity. The statistical summaries of monitoring events at service areas shows 2～15 days for ADD (Antecedent Dry Days), 3～76 mm for total rainfall, 1～11 hrs for runoff duration and 0.8～7.0 mm/hr for average rainfall intensity. The statistical summaries of monitoring events at a slope shows 2～13 days for ADD (Antecedent Dry Days), 3.43～27.32 mm for total rainfall, 1～22.4 hrs for runoff duration and 1.22～8.79 mm/hr for average rainfall intensity.

Table 2. The statistical summaries of monitoring events at expressways, tollgates and service areas

	Expressway				**Tollgate**				**Service Area**			
	ADD	**Total Rainfall**	**Runoff Duration**	**AVG INT**	**ADD**	**Total Rainfall**	**Runoff Duration**	**AVGINT**	**ADD**	**Total Rainfall**	**Runoff Duration**	**AVGINT**
N of cases	59	59	59	59	33	33	33	33	10	10	10	10
Minimum	2	1.5	1	0.3	2	3	0.5	0.8	2	3	1	0.8
Maximum	18	79	23	24	15	77.5	20	9.0	15	76	11	7
Median	4	17.15	4.2	4.3	6.5	10.0	6.1	3.1	4	7	2.75	3.96
Mean	5.458	23.354	5.063	5.722	6.727	17.648	6.136	3.221	4.9	16.85	3.5	4.332
95% CI Upper	6.572	28.833	6.125	7.014	7.946	23.706	7.770	3.860	7.607	32.644	5.592	5.839
95% CI Lower	4.343	17.876	4	4.431	5.509	11.591	4.503	2.583	2.193	1.056	1.408	2.825
Standard Dev	4.277	21.023	4.076	4.956	3.436	17.083	4.608	1.801	3.784	22.078	2.925	2.106

Average pollutant EMCs at expressways were determined to 79.52mg/L for TSS, 166.89 μg/L for tot Cu, 458.42 μg/L for tot Pb, 291.4 8 μg/L for tot Zn. Average pollutant EMCs at tollgates were determined to 80.24mg/L for TSS, 93.89 μg/L for tot Cu, 497.85 μg/L for tot Pb, 334.15 μg/L for tot Zn. Average pollutant EMCs at service areas were determined to 108.47 mg/L for TSS, 118.17 μg/L for tot Cu, 345.3 μg/L for tot Pb, 349.47 μg/L for tot Zn. Average pollutant EMCs at a slope were determined to 34.34mg/L for TSS, 90.45 μg/L for tot Cu, 421.63 μg/L for tot Pb, 246.61 μg/L for tot Zn.

Table 3. Average Pollutants EMCs at Expressway

	N of cases	Minimum	Maximum	Median	Mean	Standard Dev
TSS (mg/L)	59	20.66	284.76	59.53	79.52	56.93
BOD (mg/L)	36	2.09	155.97	12.18	18.38	26.20
COD (mg/L)	34	5.75	162.20	21.29	27.03	27.90
DOC (mg/L)	59	0.00	41.19	10.12	11.54	7.89
TN (mg/L)	59	0.00	21.89	2.69	3.72	4.40
TP (mg/L)	59	0.01	3.81	0.36	0.59	0.83
TOT_CU (μg/L)	59	0.00	928.16	111.12	166.89	181.44
TOT_PB (μg/L)	59	1.36	7025.00	153.24	458.42	983.43
TOT_ZN (μg/L)	59	0.08	3500.29	144.50	291.48	489.73

The pollutant EMCs for expressways were determined at six rainfall ranges. The TSS EMCs shows the highest value at the rainfall range of 40＜R≤50 and the lowest value at R≤10.

Table 3. Runoff Rate of Expressway

Rainfall ranges	No. of events	Runoff coefficient for each rainfall range (Ry)	Rainfall occurrence frequency for each rainfall range (fx)	Ry * fx	Runoff rate Rz
R≤10	21	0.7	18.8	13.4	0.65
10＜R≤20	14	0.6	15.7	8.8	
20＜R≤30	9	0.7	12.3	8.2	
30＜R≤40	4	0.7	13.6	9.9	
40＜R≤50	2	0.1	2.2	0.2	
50＜R	9	0.7	37.4	24.6	

Determination of Pollutant Unit Load

The pollutant unit load can be determined using the pollutant EMCs, runoff rate and yearly total rainfall. The runoff rate can be determined using average runoff coefficient and rainfall occurrence frequency for each rainfall ranges.

When the determined unit load was compared with other unit loads, the unit load from this study were lower than the unit load of Korea MOE and higher than other countries.

Table 4. Comparison of Unit Loads

Parameters	Unit load from this study (kg/㎢·day)	Unit load of Korea MOE (kg/㎢·day)	Average unit load from other countries (kg/㎢·day)
TSS	188.5	-	62.6
BOD	43.6	85.9	2.4
COD	64.1	-	20.3
DOC	27.4	-	-
TN	8.81	13.69	-
TP	1.40	2.1	0.28
Total Cu	0.40	-	0.05
Total Pb	1.09		0.07
TotalZn	0.69		0.2

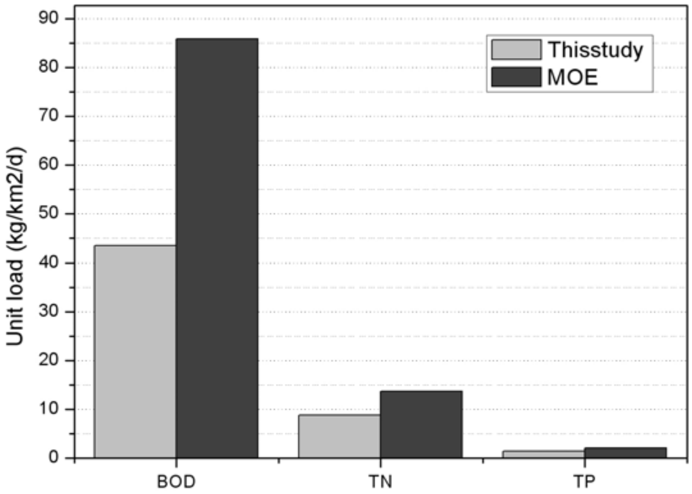
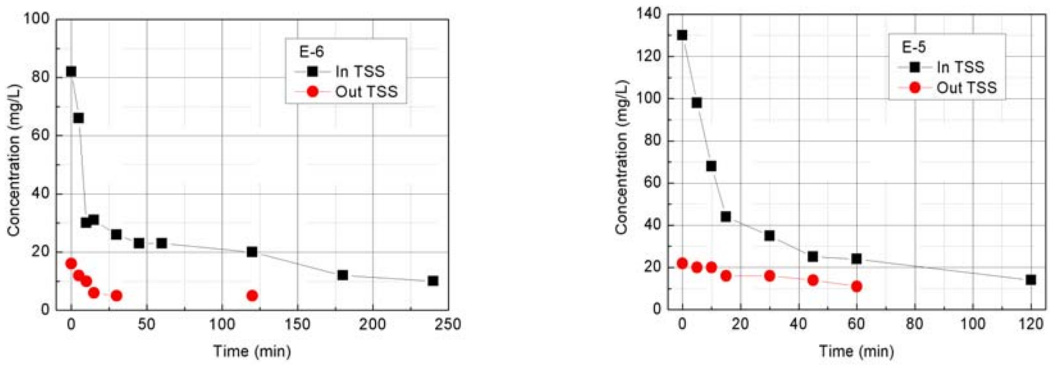


Figure 3. Comparison of Unit Loads

Evaluation of BMP Facilities

The monitoring were performed on 10 rainfall events for SWT1 and 6 rainfall events for SWT2 during operating the facility. The operation time were ranged to 1-11hrs and average influent flow rate were ranged to 0.68～51.38 m^3/day for SWT1. In the case of SWT2, it was operated to 0.3～4.8hrs for operation time and 3.60~17.34 m^3/day for average influent flow rate. The water quality parameters and flow rates were monitored during a storm. The influent TSS concentrations were ranged to 6.0～434.1 mg/L and effluent TSS concentrations were ranged to 5.0～305.0 mg/L.

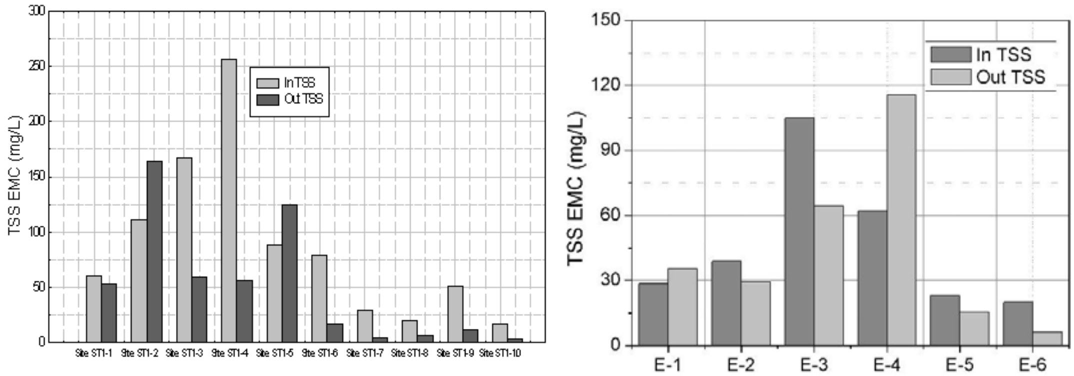


(a) Event 5 (b) Event 6

Figure 4. Concentration of Influent and effluent

TSS concentrations for SWT1 were ranged to 16.5～253.9 mg/L for influent and 3.8～164.4 mg/L for effluent. In the case of SWT2, the influent TSS EMCs were ranged to 19.9～104.8 mg/L and the effluent TSS ranges were 6.2～64.2 mg/L.

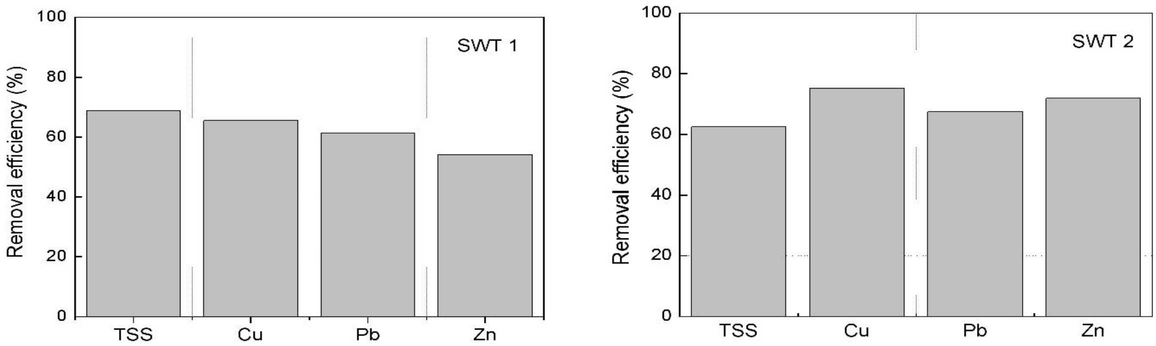
In the case of SWT1 BMP, average TSS removal efficiency was 68.9%, 65.4% for tot Cu, 61.3% for tot Pb and 54.2% for tot Zn. The removal efficiencies show the high value for all water quality parameters. In SWT2, the average removal efficiencies show 62.5% for TSS, 67.4% for tot Pb and 71.8% for tot Zn



(a) SWT 1 (b) SWT2

Figure 5. EMCs of influent and effluent for BMPs

The BMPs using the mechanisms of sedimentation and filtration are useful to treat the particulate and metal materials. For these pollutants, the removal efficiencies for all the water quality parameters were higher than 50%. It means that these kinds of mechanism can be useful for treating the stormwater runoff from the expressways.



(a) SWT 1 (b) SWT 2

Figure 6. Pollutant Removal Efficiency of the BMPs

4. CONCLUSIONS

1. Korea MOE (Ministry of Environment) has made the new water quality program, which are Total Daily Maximum Load (TMDL) and NPS control program. In these programs, the expressway construction projects are classified as the landuse requiring best management practices (BMPs) for NPS pollutant control.
2. However, current TMDL program in Korea is using only one pollutant unit load for urban landuses to determine the possible pollutant loadings after construction. Actually the urban areas are including various landuses, which are residential, commercial, industrial, transportation such as expressway, parking lot, road, etc. Of the various landuses in urban areas, the transportation landuse is the area accumulating lots of NPS pollutant during dry seasons because of vehicle and human activities.
3. Therefore, the objectives of the research were to determine the pollutant unit load from expressway landuses. It were determined by performing monitoring during a storm at various expressway landuses.
4. From this research, the following results were determined:
   - The pollutant unit loads were determined to 43.6 kg/㎢·yr for BOD, 8.81 kg/㎢·yr for TN, 1.40 kg/㎢·yr for TP.
   - Long-term monitoring is really needed to determine the appropriate pollutant unit load. Therefore, in order to have useful unit load, more monitoring will be needed.
   - BMPs having the mechanism of sedimentation, infiltration and filter show the high removal efficiency, higher than 70% for particulate materials and more than 50% for metals, resperctively.

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